Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 153 (2016) 461 – 466

Procedia Engineering

www.elsevier.com/locate/procedia

XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering"

The level of airtightness in energy-efficient single-family houses in Poland

Artur Miszczuk[a]*

[a]Warsaw University of Technology, Faculty of Civil Engineering, Institute of Civil Engineering, Team Building and Sustainable Development Al. Armii Ludowej 16, 00-637 Warsaw, Poland

Abstract

The article presents the results of the research concerning tightness in the single family houses with superior energy. The first part contains of the main requirements for the tightness of the building contained in the Polish norms, European standards and National Fund for Environmental Protection and Water Management. In order to reach conclusions quantitative and qualitative research of tightness of the buildings energy-efficient and passive single family houses have been conducted. Test procedure was based on the PN-EN ISO 9972:2015. The results indicate in some buildings deviations from the requirements specified in the standards.

Peer-review under responsibility of the organizing committee of the XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering".

Keywords: air tightness of the building; blower door; building energy-efficient; mechanical ventilation

1. Disclosure preservation of the building's tightness

The tightness of the building's envelope is maintaining the highest limit air circulation between the internal environment and the outside part of the building. Low tightness of the building entails a number of risks for both the building and its users. The main threats include :

* Corresponding author. Tel.: +48-22-234-65-97.
E-mail address: a.miszczuk@il.pw.edu.pl

1877-7058
Peer-review under responsibility of the organizing committee of the XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering".
doi:10.1016/j.proeng.2016.08.158

- The appearance of interstitial water vapor condensation
- The risk of development of mold
- Decrease of room acoustics

In the case of energy-efficient and passive buildings we should pay a particular attention to the air-tightness. A key role in the energy balance of the total buildings, even a small loss of energy. Very often achieving desired, very low power demand depends on the tightness of the partitions. [4]

2. Requirements

2.1. International requirements

Signing of the Directive on Energy Performance of buildings (EPBD) by the countries of the European Union, forced to strive to reduce energy consumption in buildings. In the individual countries have adopted provisions for reducing air infiltration to/from buildings.

Table 1. Acceptable level of air-tightness in European buildings [1,5,6].

Country	Requirements tightness with a difference of 50 Pa	
	Gravity ventilation	Mechanical ventilation
Poland	3,0 h^{-1}	1,5 h^{-1}
Germany	3,0 h^{-1} or 7,8 m³/h on m² surface floor	1,5 h^{-1} or 3,9 m³/h on m² surface floor
Czech republic	4,5 h^{-1}	Without heat recovery: 1,5 h^{-1} With heat recovery: 1,0 h^{-1}
Lithuania	3,0 h^{-1}	1,5 h^{-1}
Great Britain	New buildings, service buildings and public buildings above 500 m²:	10 m³/m²·h

Some countries, such as Poland, the Czech Republic and Germany have different requirements for gravity and mechanical system ventilation (Table 1). The cause of the mechanical ventilation is operating at a higher differential pressure (exhaust ventilation) [2].

The tightness of the building is described frequently as a number of air exchanges in a building within 1 hour - n_{50} [h^{-1}] (this is the ratio of the flow of air leak at a pressure difference of 50 Pa (V_{50}) to the volume of the internal (V)) (equation 1).

$$n_{50} = \frac{V_{50}}{V} \quad [h^{-1}] \tag{1}$$

The exact methodology whereby should be perform a research tightness of the building was presented to the European standard PN-EN ISO 9972:2015 [7], which also applies in Poland.

In most EU countries there is no obligation to carry out a research tightness, it is only recommended. There is also no legislation concerning the increase of the buildings tightness designed as passive or energy-efficient.

In the case of requesting a certificate (by PHI or BBC-Effinergie) perform a research tightness is required for energy-efficient or passive building. Tightness of the building for passive building (certificate PHI Darmstadt) should be ensured at the level of $n_{50} \leq 0{,}6h^{-1}$. The French system of certificate (BBC-Effinergie) needs to ensure the tightness of single-family better than 0.6 $m^3/(h \cdot m^2)$ for differential pressure 4 Pa or 1,0 $m^3/(h \cdot m^2)$ in the case of collective residential buildings [2].

2.2. National requirements.

Requirements for air-tightness of new buildings specified in the Technical Conditions [8]:

"2.3.3. The recommended air tightness of buildings is: in buildings with gravity ventilation or hybrid ventilation - $n_{50} < 3,0\ h^{-1}$ in buildings with mechanical ventilation or air conditioning - $n_{50} < 1,5\ h^{-1}$.

2.3.4 It is recommended that after the construction of residential, collective residential, public and production has been subjected to tightness test...".

Replacement of the Technical Conditions [8] the word "required" with the word "recommended", the provision becomes completely dead and the vast majority of investors/developers do not carry out such a research.

On the same as in the case of France and Germany, in Poland there is also an institution (National Fund for Environmental Protection and Water Management), which "appreciates" investors rising energy-efficient (NF40) and passive (NF15) buildings. In order to obtain appropriate financing, the building has to through a validation process which includes, among other things a tightness research of shell. To qualify the building for standard NF40, a tightness should meet the terms $n_{50} \leq 1,0\ h^{-1,}$ and for NF15 respectively $n_{50} \leq 0,6\ h^{-1}$.

3. Research

In order to check the level of tightness current rising buildings in Poland to which investor assumed that energy-efficient buildings should have carried out research in accordance with standard PN-EN ISO 9972:2015 [7].

3.1. Procedure of conduct research

The research has been classified buildings:

- Single-family
- Passive or low energy
- Equipped with mechanical ventilation with heat recovery
- Located in different climatic zones in Poland
- Built in recent years (most of the buildings were built after 2010)

The process of research [7]:

- Check if weather conditions allow to carry out research
- Preparing the building for research (including the closure or blockage of individual holes)
- Location of any tightness, their document and sealing
- Execution of the target measurement (measurement of differential pressure and air flow)
- Preparation of the final report of the research

3.2. Research results

25 buildings classified to the research considering the tightness of the outer shell. On the grounds of unfavorable weather conditions such as wind speed exceeding the permissible value of 6m/s specified in the standard [7] and the strong blasts and changes in wind direction, which could contribute to falsifying the results, the research was conducted on 22 buildings (Table 2).

Table 2. Summary of research results and calculations.

Location		Częstochowa	Kluczbork	Krakow		Lublin		Lodz	Pruszcz Gdanski	Siedlce	Pila	Strzelce Opolskie	Tarnowskie Gory					Warszawa					Wroclaw
Designation of the building	[-]	Cz	Kl	Kr	L1	L2	L3	Lo	PG	Si	Pi	SO	TG1	TG2	W1	W2	W3	W4	W5	W6	W7	W8	Wr
The heated surface of the building	[m^2]	114	140	143	135	95	125	276	109	197	161	130	145	145	113	168	141	133	102	214	140	172	138
The surface envelope	[m^2]	266	336	373	414	295	502	366	457	409	604	388	349	349	244	602	459	339	417	423	537	408	445
The tightness of the building	[h^{-1}]	3,29	0,17	1,12	2,53	1,95	3,58	2,75	3,04	0,82	0,45	1,51	4,02	3,62	5,33	4,74	0,86	3,55	0,63	2,43	1,93	1,44	3,46

Design solutions tested buildings:

- Foundation - most of the buildings have a foundation bench, only four buildings (L3, PG, TG1, TG2) they found sited on the foundation plate
- Walls - four buildings (C, L2, Pi, W4) have a lightweight construction walls (wooden structure filled thermal insulation), the remaining buildings are characterized by a brick structure
- Roof - all buildings have a lightweight construction (wooden structure filled thermal insulation)

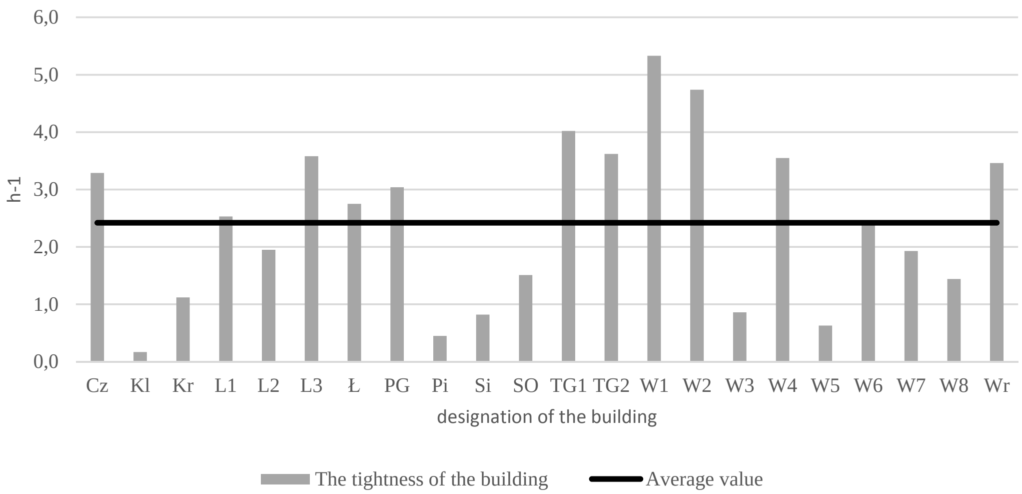

Fig. 1. Level of air-tightness of the building.

The analyzed buildings have different levels of tightness (from n_{50} = 0,17 to 5,33 h^{-1}). Most of them exceeded recommended for buildings with mechanical ventilation of air infiltration (n_{50} < 1,5 h^{-1}) [8]. The average value of air infiltration was n_{50} = 2,4 h^{-1} (figure 1), it exceeds more than 1,5 times the limit value.

Reference has been made also for air tightness of the building to the surface of the partitions which lead to the uncontrolled flow of external air. (Figure 2) We can formulate the following conclusion – the growth of external surfaces postpone to a small extent on the growth of the tightness of the building.

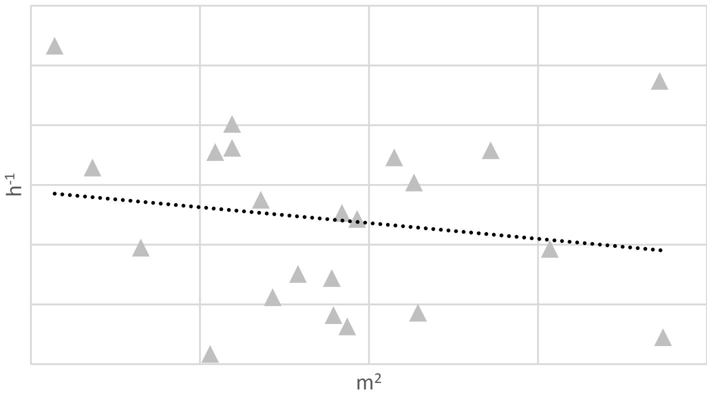

Fig. 2. The dependence of air-tightness from the external surfaces of the building.

In the case of the reference to the tightness of the building usable surface (Figure 3) – growth area of the building slightly improves the tightness.
The most common leakage include:

- Connection window frames/door with jambs
- Combination of different types of envelope (floor-wall, roof-wall, ceiling-wall)
- Transition system (plumbing, electrical, ventilation, heating and others) by envelope [3]
- Partitions separating the heated part from the unheated.

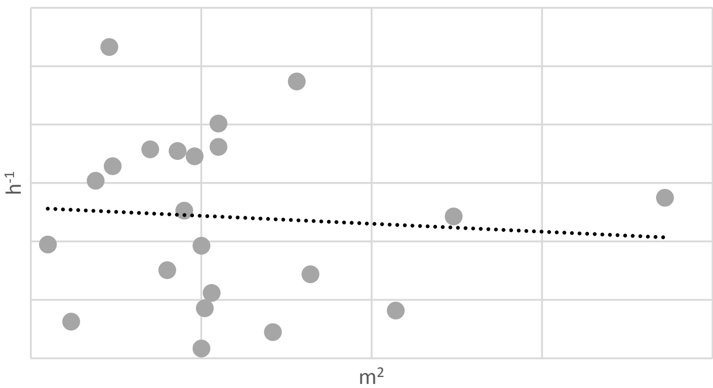

Fig. 3. The dependence of air-tightness from floor area of the building.

4. Overview

The research were obtained appropriate the tightness of the outer casing for each of the buildings. Level of tightness of the buildings (as mentioned earlier) decomposes in the range from n_{50} = 0,17 to 5,33 h^{-1}.

The analyzed buildings were characterized by a different structure of the walls, which do not significantly affect level of airtightness. Both the building with the worst (W1) as the best (KI) level of tightness has the same wall construction (brick walls).

Reaching the lower than projected in the normal of the tightness building was mainly the human factor. Lack of experience and inaccurate performance coatings tight building envelope, especially at the location of the odes structural contributed to the flow of outdoor air and a considerable energy loss.

Very often committed basic mistakes when implementing insulating air-tight which strongly influences the level of airtightness of the building.

The most common places mistakes are made of porous transition install the by the envelope and leaks vapor barrier at connections.

References

[1] Erhorn-Kluttig H., Erhorn H, Lahmidi H, Airtightness requirements for high performance building envelopes, ASIEPI European project, Report P157, 05.03.2009
[2] Firląg Sz., Szczelność powietrzna budynków pasywnych i energooszczędnych – wyniki badań, Czasopismo Techniczne, Wydawnictwo Politechniki Krakowskiej, Zeszyt 3, rok 109.
[3] Firląg Sz., Miszczuk A.; Szczelność powietrzna budynków energooszczędnych a instalacje, miesięcznik Rynek Instalacyjny 4’2015, Warszawa 2015.
[4] Miszczuk A., Żmijewski K.; Analiza rynku budynków o niskim zapotrzebowaniu na energię w Polsce, miesięcznik Materiały Budowlane 1’2015, Warszawa 2015.
[5] Peuhkuri R., Tschui A, Pedersen S, Application of the local criteria/standards and their differences for very low-energy and low energy houses in the participating countries, NORTHPASS European project, Report, 12.03.2010.
[6] Conservation of fuel and power in new dwellings, HM Government, 2013.
[7] PN-EN ISO 9972:2015; „Cieplne właściwości użytkowe budynków -- Określanie przepuszczalności powietrznej budynków -- Metoda pomiaru ciśnieniowego z użyciem wentylatora”
[8] Rozporządzenie Ministra Transportu, Budownictwa i Gospodarki Morskiej z dnia 5.VII.2013 zmieniające rozporządzenie w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie;